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**SEARCH AREA AND TARGET DETECTABILITY
ON A PPI CATHODE-RAY TUBE**

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Aero Medical Laboratory

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FOREWORD

This report is the result of experiments performed by Barbara Beach Buckley under the direction of Randall M. Hanes under contract No. AF33(038)-22642 at the Institute for Cooperative Research, the Johns Hopkins University. The report was prepared by James Deese. The contract was initiated under a project identified by Research and Development Order Nos. 694-45, Presentation of Data on Radar Scopes, and 694-43, Human Engineering Analysis of Multiple Operator Air-Ground Systems, and was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with Julien M. Christensen acting as Project Engineer.

ABSTRACT

The present experiments investigated the effect upon detection thresholds of small signals on a 7-in. PPI radar scope of viewing only a portion of the scope rather than the whole scope. If there is a search factor in detection, it would be expected that viewing only a portion of the scope would result in lower thresholds. Two methods of dividing the scope were used. In one method the observer viewed either the right or left sector. In the other method the observer viewed the outer or inner portions (dividing the radius in half). Thresholds for detection of small targets under these conditions were compared with thresholds obtained with search of the whole scope. The location of targets was randomized so that observers could not predict where they would appear.

When the unused portion was masked by black paper the thresholds for the outer-inner division were significantly lower than those for the whole scope or for right-left division. Right-left division was not different from search of the whole scope. When the unused portion of the scope is not masked or when two observers are used simultaneously searching different parts of the same scope, there is either no difference or a very small difference between use of part of the scope and use of the whole scope. Thus it seems that only when the unused portion of the scope is masked off is search of part of the scope better than search of the whole scope.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:



ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

I. INTRODUCTION

Schafer (1) has pointed out, in connection with an analysis of sonar detection data, that the probability of detecting a target on some displays can be improved by the addition of a second observer watching the same incoming data. Schafer's report was written as the result of a suggestion by Williams (3) that detectability might be improved by the use of two observers.

In his report, Williams (3) showed some evidence that suggests that, for rather small targets, detectability could probably be improved by having the observer watch only a portion of the scope rather than the whole scope. Such an effect Williams called the search factor in radar detection. Williams' study showed that the search factor worked only in the case of relatively small targets and that the effect was rather small. It was large enough, however, to suggest to him that if two or more observers are used in the detection of signals that there might be some optimal way of combining them. In his report he suggested that a test of the best way to combine two observers could be made by comparing different ways of dividing a scope into two parts. It is to this problem that the present report is addressed.

II. PROCEDURE

The apparatus and room used in this experiment have been described in detail in several reports (see particularly 4). The following description outlines the details of the operating conditions of the present experiment.

The simulated targets appeared as traces brighter than the scope background on the face of a 7BP7 (VD 2 Repeater) cathode ray tube. This tube had been in operation for more than 200 hr at the time of the experiment. The targets themselves were one microsec (3^0) in length with a pulse repetition rate of 2000 times per second. No video noise was used. The rotation rate of the sweep line was 6 rpm. The CRT grid bias was -25 v, the accelerating voltage (second anode) was 5000. The target reference for standardization was 3 db (15 v peak). The ambient illumination at the face of the scope was 3.8×10^{-3} ft-c as measured by a Macbeth illuminometer. The apparatus was continuously monitored and was standardized at approximately one-half hour intervals to correct any drift. The same CRT was used throughout the experiment.

Subjects. Twenty-four subjects, unselected except for lack of visual defects, were used in this experiment. They were all male undergraduate students except one, who was a female laboratory technician.

Method. A practice session was given at the beginning of each day's session. Actual measurement of thresholds did not take more than 1 hr per day. All subjects were given a brief rest approximately at the end of the first half-hour of observing.

The subjects were seated before the CRT at a distance of 18-24 in. There was some ambient illumination present in the room at all times. The subjects were given an opportunity to adapt to the prevailing illumination, at which time practice measures were begun. An intercommunication system enabled the subject to report targets to the operator who monitored the equipment and recorded data in another room. Subjects were always given information (right or wrong) after every response.

Targets. Forty target positions were used in this study. These positions were at four ranges (4, 8, 13, and 17 miles) and ten azimuths (at 30° intervals excluding 180° and 360°). The observers reported targets in terms of clock-reading, i.e., they reported "target at 10:00," etc. If the experimenter had any reason to believe that the observer was reporting anything but a target, he also asked the observer to give him approximate range.

Thresholds. Thresholds were recorded in terms of decibels of attenuation of target voltage. During the practice trials it was possible to obtain a rough determination of the observer's threshold. Targets during the actual experiment were started at a point below threshold and gradually increased in intensity until they were reported. The sweep line made two complete revolutions at each intensity; if no target was reported the intensity was increased by half-decibel steps until a target was reported. Targets were presented in a randomized order so that subjects could not predict the next location of a target except that it would not be at the same spot. The truncated (ascending only) method of limits was used in this experiment; it is that used in nearly all experiments with cathode ray tubes; the nature of the excitation on this tube face and its decay make this the most practical method (4).

Division of search. The purpose of the experiment was to determine any differences in average threshold associated with different ways of dividing the scope in two. Three methods of arranging the area to be searched were investigated. These were: (i) whole, in which the subjects were responsible for reporting targets appearing on the entire face of the scope, (ii) right-left, in which the subjects were required to report targets appearing only in one half of the scope, and (iii) outer-inner, in which subjects were required to report the targets appearing either in the outer or inner half of the scope (divided by radius).

Methods of division. Three separate experiments were performed using the types of division outlined in the previous section. These three experiments used two different methods of division and two different ways of assigning subjects to the search. In the first experiment single observers were used. The portion of the scope not used was masked with black masking tape. Thus

the observers could not watch the portion of the scope unassigned. In the second experiment single subjects were also used, but this time the portion of the scope not to be searched was left unmasked. In the third experiment pairs of subjects were used. Each subject was instructed to search a particular portion of the scope. Thus subjects worked together with the portion of the scope not to be searched not masked and at the same time viewed by a second observer.

III. RESULTS AND DISCUSSION

The results of the experiment on single subjects with the unused portion of the scope masked are presented in Table 1. The values in this table are mean thresholds in db attenuation, so that the higher the value the lower the threshold. An analysis of variance of the data presented in Table 1 is given in Table 2. This analysis indicates that differences in type of search area resulted in a statistically significant effect. Likewise, subjects and range produced statistically significant differences in threshold. Furthermore, there is a significant interaction between range and type of search.

An inspection of the data in Table 1 shows that any difference ascribed to type of search is almost entirely the result of superiority (in terms of lower thresholds) for the condition of searching by annular division. Furthermore, this superiority is greater for the inner ranges than for the outer ones, thus accounting for the range-search interaction. On the average, search by annular division produced thresholds a little more than 1 db better for outer ranges and about 3 db better for inner ranges. Search by right-left division does not differ for either the inner or outer ranges from search of the whole scope. A lack of advantage for sector-division may be due to the inability of the observer to follow the sweep (2).

In the second experiment the conditions were exactly the same as those in the first except that the unused portion of the scope was not masked. The results of this experiment are shown in Table 3, which gives mean thresholds in db attenuation. Table 4 shows the analysis of variance of data for this experiment. This analysis clearly shows that there is no effect of type of search. As before, the effects of range and subjects are highly significant.

In the third experiment pairs of subjects were run without mask. Table 5 shows the mean thresholds in db attenuation for this experiment. The analysis of variance of the data from this table is presented in Table 6. Table 6 shows that type of search produced a difference significant at the 5% level. An inspection of the means in Table 5 reveals that the method of searching the whole scope produced the best mean thresholds. The differences are extremely small, however, and of no practical significance.

Table 1

Mean Thresholds in Decibels of Attenuation of Target Voltage when Single Observers Search the Whole or Portions of the Scope with Unused Portions of the Scope Masked

Subjects	Search of Whole Scope		Search of Right or Left Sector		Search of Inner or Outer Annulus	
	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)
Mey	32.4	26.3	31.8	27.4	31.4	29.5
Beh	27.7	24.8	27.5	24.3	28.6	24.1
Fox	31.6	27.6	32.5	26.3	33.1	30.9
Bea	32.4	26.6	32.1	26.7	33.5	31.2
Kin	29.5	25.4	30.7	25.5	32.3	29.1
Bet	31.5	25.9	29.5	26.6	29.2	29.8
Total	185.1	156.6	184.1	156.8	188.1	174.6
Mean	30.85	26.10	30.68	26.13	31.35	29.10
Mean	28.48		28.41		30.23	

Table 2

Analysis of Variance of Data Presented in Table 1

Source of Variation	Sums of Squares	<u>df</u>	Mean Square	<u>F</u>
Division of Scope	22.56	2	11.28	12.40*
Ranges (outer vs. inner)	130.50	1	130.50	143.40*
Subjects	72.51	5	14.50	15.93*
Division X Subjects	12.53	10	1.25	1.37
Division X Ranges	14.48	2	7.24	7.96*
Ranges X Subjects	6.30	5	1.26	1.38
Division X Ranges X Subjects	9.05	10	0.91	
Total	267.94	35		

* Significant at the 1% level or beyond.

Table 3

Mean Thresholds in Decibels of Attenuation of Target Voltage when Single Observers Search the Whole or Portions of the Scope with Unused Portions of the Scope not Masked

Subjects	Search of Whole Scope		Search of Right or Left Sector		Search of Inner or Outer Annulus	
	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)
Pit	28.4	24.3	27.2	23.4	28.5	24.2
Amr	28.7	25.9	29.4	26.7	27.7	28.0
Eng	27.6	25.8	28.5	26.0	28.5	27.8
Fis	27.2	23.8	27.3	24.0	26.8	26.7
Gat	30.2	26.6	30.2	27.3	29.0	26.6
Kap	29.3	25.2	29.8	26.0	25.6	27.4
Total	171.4	151.6	172.4	153.4	166.1	160.7
Mean	28.57	25.27	28.73	25.56	27.68	26.78
Mean	26.92		27.15		27.23	

Table 4

Analysis of Variance of Data Presented in Table 3

Source of Variation	Sums of Squares	<u>df</u>	Mean Square	<u>F</u>
Division of Scope	0.65	2	0.33	-----
Ranges (outer vs. inner)	54.27	1	54.27	62.45
Subjects	26.72	5	5.34	6.14
Division X Subjects	8.36	10	0.84	-----
Division X Ranges	38.46	2	19.23	22.13
Ranges X Subjects	6.36	5	1.27	-----
Division X Ranges X Subjects	8.69	10	0.87	
Total	143.51	35		

Table 5

Mean Thresholds in Decibels of Attenuation of Target Voltage when Pairs of Observers
Search the Whole or Portions of the Scope with No Portion of the Scope Masked

Subjects	Search of Whole Scope		Search of Right or Left Sector		Search of Inner or Outer Annulus	
	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)	Outer Range (13 & 17 mi.)	Inner Range (8 & 4 mi.)
Mc Car	28.00 30.88	28.91 29.38	29.63 29.43	28.88 28.60	29.85 30.85	30.35 27.95
Der Cho	29.45 29.57	27.59 27.94	27.68 29.55	25.05 26.30	27.53 30.90	28.15 28.13
Bis Bac	30.88 30.86	29.27 29.14	30.15 30.73	28.05 27.78	30.35 30.38	29.75 28.60
Pir Kal	28.73 29.00	26.41 26.85	29.40 29.15	26.95 26.73	30.50 28.00	26.60 26.88
Pal Pou	28.33 28.29	26.05 25.52	27.25 27.90	23.53 25.70	26.28 28.30	23.85 24.55
Sm Bie	29.94 30.31	27.25 26.05	29.70 29.35	26.48 26.10	28.05 30.78	27.73 24.00
Total	354.24	330.36	349.92	320.15	351.87	326.54
Mean	29.52	27.53	29.16	26.68	29.32	27.21
Mean	28.53		28.27		27.92	

Table 6

Analysis of Variance of Data Presented in Table 5

Source of Variation	Sums of Squares	<u>df</u>	Mean Square	<u>F</u>
Division of Scope	4.43	2	2.22	3.53**
Ranges (outer vs. inner)	86.64	1	86.64	137.93*
Subjects	94.70	11	8.61	13.71*
Division X Subjects	16.65	22	0.76	-----
Division X Ranges	0.78	2	0.39	-----
Ranges X Subjects	23.41	11	2.13	3.39**
Division X Ranges X Subjects	13.82	22	0.63	
Total	240.43	71		

* Significant at the 1% level.

** Significant at the 5% level.

Thus, it seems clear that there is no advantage to dividing the scope either by annuli or by sectors when two observers are used at the same scope. The answer to the question originally raised by Williams, for small scopes at least, seems to be that the best way to use two observers watching the same incoming data on the same scope is to have them both watch the same area.

The slight superiority of searching by annular division when the unused portion of the scope is masked is possibly of some practical value. If two observers are watching the same incoming data on different scopes, it may be of value to use masks. Or, for that matter, in certain types of search where only one observer is used, it may be of value to provide removable masks for the inner portion of the scope, since for initial detection the outer portion of the scope is likely to be the only area used.

The data of Williams (3) suggest that the presence of noise on the scope ought to increase the advantage of searching part of the scope over searching the whole scope. Under conditions of noise the relative advantage of annular division over the other methods of search when the unused portion of the scope is masked out ought to increase. There is little reason to expect, however, that a noisy background would make the use of two observers each searching a half-sector of the scope better than two observers each searching the whole scope, at least for small scopes of the size used in this experiment, because the critical factor seems to be the necessity of forcing the observer to watch only the assigned portion. For larger scopes it is possible that somewhat different results would be obtained. From the present data and from Williams' data it seems likely that search by annular division under masking would result in relatively greater advantage in the case of a larger display. Both the present experiment and Williams' data suggest that there would be no advantage of part over whole scope search for a larger display when the unused portion was not masked out.

IV. SUMMARY

The present experiment tested the possibility that the detectability (thresholds) for small targets on a radar scope could be improved by having observers search part of the scope rather than all of it. The experiment was particularly concerned with possible ways of assigning two observers to watch the same incoming data.

The results of the present experiment show that there is a small but consistent advantage of searching part of the scope when divided by annuli over searching the whole scope or searching part of it when divided by sector. The largest advantage is obtained with targets occurring at the inner ranges,

though there is some advantage obtaining with targets that occur in the outer ranges. This advantage of annular division holds only, however, when the unused portion of the scope is masked off from view. There is no advantage when the observer is merely instructed to search part of the scope. When two observers are used together on the same scope, there seems to be a very slight advantage to search of the whole scope by each observer.

The results of this experiment suggest that for small scopes (7-in. diameter) there is little or no advantage to be achieved by dividing the scope between two observers. If two observers are to be used in observing the same incoming data, it is probably best to have them both search the entire scope.

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